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THE IMPACT OF REAFFORESTATION ON THE PRODUCTION OF NATURAL ECOSYSTEMS - A STUDY CARRIED OUT IN SANTANDER, ASTURIAS AND VIZCAYA

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INTRODUCTION

When looking at the results of the extensive reafforestations carried out during the last 45 years in Spain, it is impossible to overlook their influence on the already existing natural ecosystems.

In 1939 J. Ximénez de Embún and L. Ceballos developed a national reforestation plan which was put into effect in 1940. The aim was to replant 6 million ha with high forest during a period of 100 years, in view of both productive and protective objectives. It was estimated that an average of 60,000 ha per year should be planted. Figures showing how this was achieved so far are shown in Table 1.

TABLE 1:

Years	Area planted	Yearly average for the decade
1940-50	304,977 ha	27,725 ha
1950-60	1,173,531 ha	86,855 ha
1960-70	1,902,845 ha	72,931 ha
1970-80	2,409,218 ha	50,637 ha
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annual average of work carried out:		58,761 ha

(Source: I.C.O.N.A. Report 1983)

The area of reafforestation with main tree species up to 1983 is given in Table 2.

TABLE 2:

Species	Surface area
Pinus sylvestris	572,297 ha
Pinus uncinata	17,886 ha
Pinus laricio	389,067 ha
Pinus pinaster	800,688 ha
Pinus radiata	168,051 ha
Pinus pinea	231,747 ha
Pinus halepensis	499,249 ha
Pinus canariensis	27,556 ha
Other conifers	24,028 ha
TOTAL coniferous trees	2,730,569 ha
Populus sp.	27,431 ha
Eucalyptus sp.	273,911 ha
Other decidous trees	26,888 ha
TOTAL decidous trees	328,230 ha
GRAND TOTAL	3,058,799 ha

(Source: I.C.O.N.A. Report 1983)

When reading these values one cannot fail to be amazed at the vast and prodigious amount of work done.
However, it is also reasonable to suppose that this activity, affecting large areas throughout the land, will also have an impact on ecosystems and the way of life of people, both in a positive and in a negative sense (e.g. modification of the flora and fauna, of the economy, etc.).
The paper presented here is a contribution to the study of the effects which have, or in future will result from the application of the reafforestation plan.

DISTRIBUTION OF TREE SPECIES IN SPAIN

The National Forestry Map of Spain, established in 1966 by D. Luis Ceballos, was used to estimate the area occupied by different types of vegetation. A sampling method was applied with 47,764 grids of approximately 10 square km, depending on latitude. 81,978 patches of formation types including trees, shrubs, and crops were identified.
From the results obtained, the surface area occupied by each of the 23 species considered in the study of the Iberian Peninsula and the Balearic Islands, is given in Table 3.

Table 3:

Type of vegetation	Surface area in km²
Crops	221,063
Shrubs	113,671
Quercus ilex	57,686
Pinus sylvestris	11,128
Pinus pinea	5,158
Pinus halepensis	20,509
Pinus laricio	9,049
Pinus pinaster	19,050
Pinus radiata	1,647
Juniperus thurifera	2,335
Castanea sativa	4,444
Fagus sylvatica	2,819
Quercus robur	2,867
Quercus petraea	539
Quercus pyrenaica	8,955
Quercus faginea	5,763
Quercus suber	5,387
Eucalyptus sp.	2,500
Pinus uncinata	892
Abies alba	337
Abies pinsapo	27
Populus sp.	1,639
Juniperus phoenicea	43
NATIONAL TOTAL	497,508

As can be seen, the larger part of the area is covered by deciduous tree species (90,099 km² not counting the 2,500 km² of eucalyptus). Deciduous trees are generally the climax vegetation of the areas where they are found. Conifers (not counting the 1,647 km² of *Pinus radiata*) occupy 68,528 km². By subtracting the

area of reafforestation since 1940, the total area of deciduous forest in Spain, in 1940, can be estimated to have been at least 89,556 km². At the same time coniferous trees covered 39,543 km². When comparing the figures of reafforested area with the surface area of the period prior to reafforestation, the high proportion of softwood species used for reafforestation can easily be noticed.

Ratio between reafforested surface and surface in 1940:
Coniferous species.....0.636
Deciduous species.....0.006

By merely glancing at these figures we can ask ourselves why there was such a preference of softwood species for reafforestation measures.
The desire for a satisfactory answer to this question grows when observing that there has been a reduction of surface area covered with autochthonous hardwood species (analysis of the Agrarian Statistics for Spain).
Data obtained from the annual Agrarian Statistics for the years of 1946, 1966, and 1975 show the following information on deciduous trees (excluding eucalyptus):

Area covered in 1946 ... 7,377,817 ha
Area covered in 1966 ... 6,262,680 ha
Area covered in 1975 ... 5,939,477 ha

POTENTIAL EDAPHIC FORESTRY PRODUCTIVITY

The need for reafforestation was outlined in the plan of 1939 within a national forestry discussion in view of the following principles:

- Increase of Spain's forestry production by existing forest crops
- Reafforestation of clearings and open spaces within existing woodlands
- Evaluation of all direct and indirect benefits of woodland
- An increase of Spain's total forest surface.

Achieving the last of these four objectives meant to reclaim land covered by sparse shrub, degraded due to overgrazing and other activities (charcoal production, esparto grass, etc.). In many of these cases the land showed clear and visible evidence of erosion and the chance for reclaiming these areas by means of afforestation with deciduous trees were minimal. For this reason foresters resorted to coniferous trees which belonged to preclimatic states of the phytosociological series.

According to Ceballos the different Spanish pines can be planted on land formerly occupied by the main autochthonous hardwood species according to the following:

Pinus halepensis:	Quercus ilex
Pinus pinea:	Quercus ilex
Pinus pinaster:	Castanea sativa, Quercus robur, Quercus faginea, Quercus pyrenaica, Quercus suber, Quercus ilex.
Pinus nigra:	Quercus petraea, Quercus faginea, Quercus pyrenaica, Quercus ilex.
Pinus sylvestris:	Fagus sylvatica, Quercus robur, Quercus petraea, Quercus faginea, Quercus pyrenaica.

In the case of very degradated soil, or where it was necessary to regenerate a species without much light tolerance, pines were to be planted which correspond to the ecological succession of the deciduous trees thought to be the most suitable.
After the analysis of species used for reafforestation it can be said that this is not valid for *Pinus radiata* and especially not for eucalyptus trees, and also occasionally doubtful for *Pinus pinaster*.
It is clear that the reasons for planting these species are reasons of productivity.
With the aim of throwing more light on this question, Gandullo (1976) drew up the Potential Forestry Productivity Map of Spain, principally based on the productivity index established by Paterson. With this as a data bank or reference it was possible to obtain an average of potential forestry production per ha for Spain, which is 5.18 m^3/ha/annum, including crops, and 5.44 without crops. We have also found figures for average potential forestry productivity for territories occupied by the main species. See Table 4.

TABLE 4:

Species	m^3/ha/year
Pinus radiata	8.41
Quercus robur	7.88
Abies alba	7.39
Fagus sylvatica	7.29
Castanea sativa	7.20
Abies pinsapo	7.05
Pinus uncinata	6.79
Quercus petraea	6.76
Eucalyptus sp.	6.72
Pinus pinaster	6.13
Quercus suber	6.12
Pinus sylvestris	5.98
Shrubs	5.51
NATIONAL AVERAGE	5.44
Quercus pyrenaica	5.27
Juniperus phoenicea	5.19
Quercus ilex	5.04
Quercus faginea	5.01
Populus sp.	4.64
Pinus pinea	4.60
Pinus nigra	4.54
Pinus halepensis	4.12
Juniperus thurifera	3.26

As can be seen from this Table both *Pinus radiata* and *Eucalyptus* are found on soil with good potential productivity. This is also true for *Pinus pinaster* (6.13 m^3/ha/annum) when this is compared to the productivity of the climax stage of the ecological series in which it may be included. The average number of possible climaxes is 6.08 and the average measured by the surface area they occupy is 5.34 m^3/ha/annum.

REAFFORESTATION WITH ALLOCHTHONOUS PRODUCTION SPECIES

In view of these figures it can be seen that the organizations in charge of reafforestation in Spain have permitted, and even favoured (Encouragement of Forestry Production Act) the introduction of two allochthonous species: *Pinus radiata* and *Eucalyptus*, with timber productivity in mind. Logically enough, this has taken place in areas where timber production potential is good. As can also be seen, certain autochthonous, deciduous trees are situated in places where the productive capacity is large. These circumstances have occasioned the diminution of these ecosystems, which have been replaced by plantations of fast growing species, with consequent damage to our natural ecosystems.
By 1983 the area for *Eucalyptus* plantations had reached 273,911 hectares, and that of *Pinus radiata* 168,051 ha. An analysis of the data in the National Forestry Map of Spain makes it possible to go further into this question and analyse how these two species have reduced the extent of certain types of deciduous trees in the provinces of Asturias, Santander and Vizcaya.

REAFFORESTATION OF EUCALYPTUS TREES IN SANTANDER

In the province of Santander (Cantabria) located on the shores of the Cantabrian Sea in the north of Spain, vegetational formations are distributed as shown in Table 5:

TABLE 5: (Source: Forestry Map, Ceballos 1966)

Species	Surface area in km^2
Crops	515.9
Shrubs	3384.3
Quercus ilex	80.7
Pinus sylvestris	39.6
Pinus pinaster	1.6
Pinus radiata	98.5
Juniperus thurifera	8.6
Fagus sylvatica	358.9
Castanea sativa	6.8
Quercus robur	220.7
Quercus petraea	70.1
Quercus pyrenaica	110.8
Quercus faginea	3.4
Quercus suber	5.1
Eucalyptus sp.	319.0
Unproductive	35.6
Populus sp.	29.4
TOTAL	5289

This is the province in which the proportion of hectares of eucalyptus trees in relation to the size of the territory is greater.
In order to estimate where the 319 km² of *Eucalyptus* and the 98.5 km² of *Pinus radiata* have been planted, we used the vegetational data bank, and drew up a list of vegetation types which appear along with eucalyptus or Pinus radiata; these types of vegetation compete for space with the two types which have been introduced by foresters. From the above data we have supposed that surface area gained by the invading species is in proportion to the index of spatial competition. The spatial competition index has been defined as the ratio between the number of times two species border on one another and the total number of borders held by the species which have been introduced. The figures given by the data bank appear in Table 6.

TABLE 6:

	Spatial Competition Index	
Species	Eucalyptus sp.	Pinus radiata
Shrubs	74.61 %	46.67 %
Quercus ilex	3.69 %	-
Pinus sylvestris	1.22 %	5.71 %
Pinus radiata	11.88 %	-
Fagus sylvatica	1.22 %	1.91 %
Quercus robur	6.97 %	17.14 %
Eucalyptus sp.	-	27.62 %
Populus sp.	0.41 %	0.95 %

If these values are multiplied by the area occupied by eucalyptus and Monterrey pine, then the surface area occupied by already existing species can be estimated.
In this way we have been able to estimate the area lost by the different species through the introduction of *Eucalyptus sp.* and *Pinus radiata*. These values are given in Table 7.

TABLE 7:

Species	Surface area invaded, km²	Current area km²	% of current area
Shrubs	283.8	3384.3	8.38
Quercus ilex	11.5	80.7	14.25
Pinus sylvestris	9.8	39.6	24.74
Fagus sylvatica	5.8	358.9	1.62
Quercus robur	39.1	220.7	17.72
Populus sp.	2.4	29.4	8.16

It will be seen that *Pinus sylvestris, Quercus robur and Quercus ilex* have percentage diminution figures which are sufficiently high for measures to be taken to prevent a major loss of these species in the province of Santander. To us the effects on *Quercus ilex* and *Quercus robur* seem to be particularly serious; first because of the comparative rarity of evergreen oak along the Cantabrian Cornise, and second because of the scarcity of *Quercus robur* in Spain as a whole.
By way of comparing these results, we consulted the Agrarian

Statistics, which confirmed this phenomenon. (N.B.: Agrarian Statistics are not noted for their reliability). (Table 8).

TABLE 8:

Species	Surface area in km² 1946	1975	
Quercus ilex	47.94	72.93	(1)
Pinus sylvestris	-	80.55	
Quercus robur	2,198.78	162.47	

(Source: Agrarian Statistics)

(1) Statistic value, which at first glance appears to be contradictory to what we have been saying, is probably incorrect. In fact, the Agrarian Statistics give the information of Table 9, which, at the very least, is quite surprising.

TABLE 9:

Year	Surface area of Quercus ilex in Santander in km²
1946	47.94
1956	12.71
1966	9.40
1975	72.93

REAFFORESTATION OF EUCALYPTUS AND PINUS RADIATA IN ASTURIAS

In the north of Spain, between Galicia and Cantrabia, lies the Principality of Asturias. Its morphology is more abrupt than that of its neighbouring regions. In Asturias plantations of eucalyptus trees are higher in number than anywhere else in Spain. The distribution of the different species is given in Table 10.

TABLE 10:

Species	Area in km²
Crops	1,224.4
Shrubs	5,816.9
Quercus ilex	65.2
Pinus sylvestris	127.1
Pinus pinaster	668.8
Pinus radiata	226.6
Fagus sylvatica	689.9
Castanea sativa	922.2
Quercus robur	261.9
Quercus pyrenaica	45.4
Eucalyptus sp.	486.4
Populus sp.	30.2
TOTAL	10,565

(Source: Forestry Map, Ceballos 1966)

As can be seen from this Table, reforestation with eucalyptus accounts for 486.4 km², and Monterry pine for 226.6 km². An analysis was carried out equal to that which was done for Santander, with the aim of calculating the spatial competition indices for these two species. Table 11 gives these values.

TABLE 11:

Spatial Competition Index		
Species	Eucalyptus sp. %	Pinus radiata %
Crops	9.83	2.74
Shrubs	47.54	46.15
Quercus ilex	1.64	1.10
Pinus sylvestris	-	1.10
Pinus pinaster	13.11	5.49
Pinus radiata	15.30	-
Fagus sylvatica	0.54	4.94
Castanea sativa	10.38	22.52
Quercus robur	0.54	-
Eucalyptus	-	15.38
Populus sp.	1.09	0.55

Considering Table 11 as an estimation of the area invaded by the different species, we obtain Table 12.

TABLE 12:

Species	Area invaded in km²	% of current area
Crops	54.0	4.41
Shrubs	335.7	5.77
Quercus ilex	10.5	16.10
Pinus sylvestris	2.5	1.97
Pinus pinaster	76.1	11.38
Fagus sylvatica	13.79	2.00
Castanea sativa	101.53	11.01
Quercus robur	2.62	1.00
Populus	5.3	17.55

The species who's area has been invaded most in relation to the territory occupied by them are: *Populus sp., Quercus ilex, Pinus pinaster, and Castanea sativa.*
As far as this goes, both the distribution of *Populus sp.* and that of *Pinus pinaster* has increased considerably from reafforestation. Once again green oak and chestnut are regressing species in the provence of Asturias.

REAFFORESTATION WITH PINUS RADIATA IN VIZCAYA

In this provence, belonging to the Basque country, *Pinus radiata* was planted with more intensity than in any other provence of Spain. The surface area occupied is shown in Table 13.

TABLE 13:

Species	Surface in km²
Crops	635.4
Shrubs	587.8
Quercus ilex	51.8
Pinus sylvestris	5.1
Pinus laricio	1.6
Pinus pinaster	45.5
Pinus radiata	721.1
Fagus sylvatica	47.0
Castanea sativa	8.5
Quercus robur	82.5
Quercus faginea	1.6
Eucalyptus	29.1
TOTAL	2,217

(Source: Forestry Map, Ceballos 1966)

With help of the vegetational data it was, once more, possible to find the competition indices. These are given in Table 14.

TABLE 14:

Spatial Competition Index		
Species	Pinus radiata %	Eucalyptus %
Crops	22.44	10.00
Shrubs	23.62	32.50
Quercus ilex	11.41	-
Pinus sylvestris	1.18	-
Pinus pinaster	6.69	7.50
Pinus radiata	-	40.00
Fagus sylvatica	8.26	-
Castanea sativa	2.75	-
Quercus robur	16.50	10.00
Quercus faginea	0.39	-
Eucalyptus sp.	6.30	-

Given that the area occupied by *Pinus radiata* in Vizcaya is 751.1 km², and multiplying this by the competition indices, the following values are obtained and are listed in Table 15.

TABLE 15:

Invaded species	Surface invaded in km²	% of current area
Crops	164.7	25.92
Shrubs	170.62	29.02
Quercus ilex	82.2	158.68 ***
Pinus sylvestris	8.5	166.66 ***
Pinus pinaster	48.3	106.15 ***
Fagus sylvatica	59.5	126.60 ***
Castanea sativa	19.8	232.94 ***
Quercus robur	121.9	147.75 ***
Quercus faginea	2.8	175.00 ***

As can be seen, the situation in Vizcaya is alarming. The reforestation with *Pinus radiata* is sharply diminishing the area of deciduous trees in the province.
Comparison with State Statistics becomes necessary; in Table 16 the temporal regression between 1946 and 1975 of the species in question is shown.

TABLE 16:

	Surface area in km²		
Species / Year	1946	1966	1975
Quercus ilex	0.56	-	-
Fagus sylvatica	107.95	26.14	27.74
Castanea sativa	17.17	-	-
Quercus robur	86.3	44.64	20.67
Quercus faginea	-	-	-

(Source: Agrarian Statistics for 1946, 1966 and 1975)

These statistics confirm the regression of all of the climatic autochthonous species: *Quercus ilex, Castanea sativa, Quercus robur,* and *Quercus faginea* have all lost more surface area than they presently occupy. Their ecosystems are threatened by the planting of *Pinus radiata* and *Eucalyptus* for timber production.

FINAL CONCLUSIONS

The conclusions to be drawn from the analysis carried out are very clear and obviously point to the influence that plantations of rapid growth - Monterry pines and eucalyptus - have on the regression of autochthonous deciduous trees. We have seen that *Quercus ilex,* in its enclaves in the north of Spain, is undergoing severe regression. The same thing can be said of *Castanea sativa,* although in this case the diseases which the species has suffered from the "ink" (*Phytophtora cannamomi and P. cambivora*) and the cancer of chestnut trees, have in fact been the main reason for the regression, while rapid growth plantations have been a consequence of this. *Quercus robur* is another species which shows clear symptoms of regression.
On the other hand, it is impossible to forget the enormous fire risk which *Pinus radiata* and *Eucalyptus sp.* automatically imply. The figures demonstrate this: between 1970 and 1979, 532.33 km² of *Pinus radiata* plantations and 280.27 km² of eucalyptus were burned, which represents 32 % and 11.2 % of the respective surface areas estimated in 1966. By contrast, during the same period, areas of *Quercus ilex, Fagus sylvatica, Castanea sativa, and Quercus sp.* (with the exception of *Q.ilex* and *Q.suber*) burned, are respectively, 43.1 km², 2.24 km², and 14.64 km²; these represent percentages of 0.07 %, 0.08 %, and 0.33 % of the estimated surface area in 1966.
In view of these facts it seems that in certain territories, reafforestation is causing degradation of our ecosystems of autochthonous and climax species as well as increasing the risk of ecosystem destruction by forest fires. It is not necessary to point out the fact that forest fires do not only destroy trees, but also harm the remaining flora, the fauna, and leave the delicate and fertile soil exposed to erosion.

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The Impact of Reforestation On the Production of Natural Ecosystems - A Study Carried Out in Santander, Asturias and Vizcaya

Summary
In this paper the results of intensive afforestation, carried out in Spain between 1940 and 1985, are presented.
An attempt is made to analyse the extent to which these results are consistent with the principles, defined in 1939 by J. Ximénez de Embún and L. Ceballos, that inspired the afforestation.
Details of three specific cases in the provinces of Santander, Asturias and Vizcaya are given, where the development of *Pinus radiata* and *Eucalyptus sp.* and their effects on the expansion of autochtonous forests are studied.

Résumé
Dans l'exposé on etidie les résultats obtenus d'après des intenses travaux de reboisement menés à bien en Espagne entre 1940 et 1985.
On analyse aussi la fidélité aux principes initiallement prétendus et qui fûrent enoncés en 1939 par J. Ximénez de Embún et L. Ceballos.
On étude en outre trois exemples à les provinces de Santander, Asturias et Vizcaya, ou on a analysé l'evolution des reboisements de *Pinus radiata* et *Eucalyptus sp.* et leur effet sur l'étendue des bois autochthones.

Zusammenfassung
In dieser Arbeit werden die Ergebnisse der intensiven Aufforstungsarbeit studiert, die in Spanien zwischen den Jahren 1940 und 1985 ausgeführt wurde.
Es wird auch der Zusammenhang mit den Grundsätzen analysiert, die diese Aufforstung motiviert und begründet haben und wie sie 1939 von J. Ximénez de Embún und L. Ceballos formuliert wurden.
Hernach wird die Entwicklung der Aufforstungen mit *Pinus radiata* und *Eucalyptus sp.* und ihre Wirkung auf die Verbreitung der autochthonen Waldbestände in den Provinzen Santander, Asturias und Vizcaya studiert.